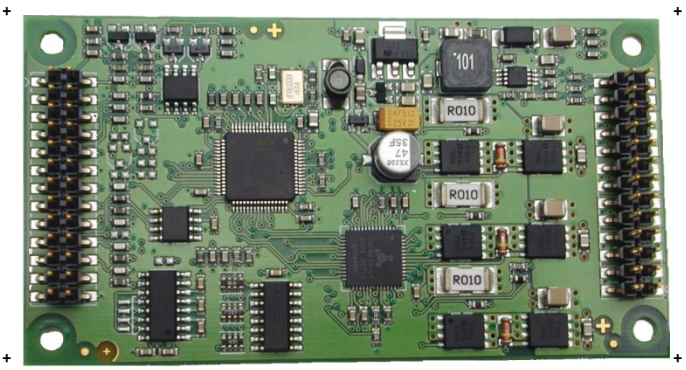
## Firmware Version V2.07

# TMCL™ FIRMWARE MANUAL



## TMCM-1630

1-Axis BLDC
Controller / Driver
10A / 48V
RS232 / CAN or
RS485 / USB

TRINAMIC Motion Control GmbH & Co. KG
Hamburg, Germany

**www.trinamic.com**

TRINAMIC
MOTION CONTROL

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# 1 Features

The TMCM-1630 is a highly integrated single axis BLDC servo controller module with several interface-options. The highly integrated module (size: 50mm x 92.5 mm) has been designed in order to be plugged onto a baseboard. It integrates velocity and position control and offers hall sensor and incremental encoder (a/b/n) inputs. The module can be used in standalone operation or remote controlled.

**Applications**
- Demanding single and multi-axis BLDC motor solutions

**Electrical data**
- Supply voltage: +24V DC or +48V DC nominal (+12… +55V DC max.)
- Motor current: up to 10A RMS (programmable) peak

**Integrated motion controller**
- High performance ARM Cortex™-M3 microcontroller for system control and communication protocol handling

**Integrated motor driver**
- High performance integrated pre-driver (TMC603A)
- Support for sensorless back EMF commutation (hall*FX*™)
- High-efficient operation, low power dissipation (MOSFETs with low $R_{DS(ON)}$)
- Dynamic current control
- Integrated protection
- On the fly alteration of motion parameters (e.g. position, velocity, acceleration)

**Interfaces**
- Two standard assembly options:
- RS232 and CAN (2.0B up to 1Mbit/s)
- RS485 and USB
- 2 analogue and 2 digital inputs
- 3 open drain outputs

**Motor type**
- Block commutated 3 phase BLDC motors with optional hall sensors / optional encoder
- Motor power from a few Watts to nearly 500W
- Motor velocity up to 100,000 RPM (electrical field)
- Common supply voltages of 12V DC, 24V DC, 36V DC and 48V DC supported
- Coil current up to 10A peak

**Software**
- TMCL standalone operation or remote controlled operation
- TMCL program memory (non volatile) for up to 2048 TMCL commands
- TMCL PC-based application development software TMCL-IDE and TMCL-BLDC available for free
- CANopen ready: CiA 301 + CiA 402 (homing mode, profile position mode and velocity mode) under development

**Other**
- Two double-row 2.54mm connectors
- ROHS compliant
- Size: 50x92.5mm²

***Please see separate TMCM-1630 Hardware Manual for additional information***

# 2 Overview

The software running on the microprocessor of the TMCM-1630 consists of two parts, a boot loader and the firmware itself. Whereas the boot loader is installed during production and testing at TRINAMIC and remains untouched throughout the whole lifetime, the firmware can be updated by the user. New versions can be downloaded free of charge from the TRINAMIC website (http://www.trinamic.com).

The firmware is related to the standard TMCL firmware [TMCL] with regard to protocol and commands. The module is based on the ARM Cortex-M3 microcontroller and the high performance pre-driver TMC603 and supports the standard TMCL with a special range of values.

The new FOC firmware V2.02 is field oriented control software for brushless DC applications. It is developed for high-performance motor applications which can operate smoothly over the full velocity range, can generate full torque at zero speed and is capable of fast acceleration and deceleration. This saves energy and quiets rotating machinery.

# 3 Putting the TMCM-1630 into Operation

Here you can find basic information for putting your module into operation. The text contains a simple example for a TMCL program and a short description of operating the module in direct mode.

**THINGS YOU NEED:**

- TMCM-1630
- Interface suitable to your TMCM-1630 with cables
- Nominal supply voltage +24V DC or +48V DC for your module
- Encoder optional
- BLDC motor
- TMCL-IDE program and PC

**PRECAUTIONS**

- Do not mix up connections or short-circuit pins.
- Avoid bounding I/O wires with motor power wires as this may cause noise picked up from the motor supply.
- The power supply has to be buffered by a capacitor. Otherwise the module will be damaged!
- Do not exceed the maximum power supply of 55V DC.
- Do not connect or disconnect the motor while powered!
- Start with power supply OFF!

## 3.1 Starting up

The following figure shows how the connectors have to be used.

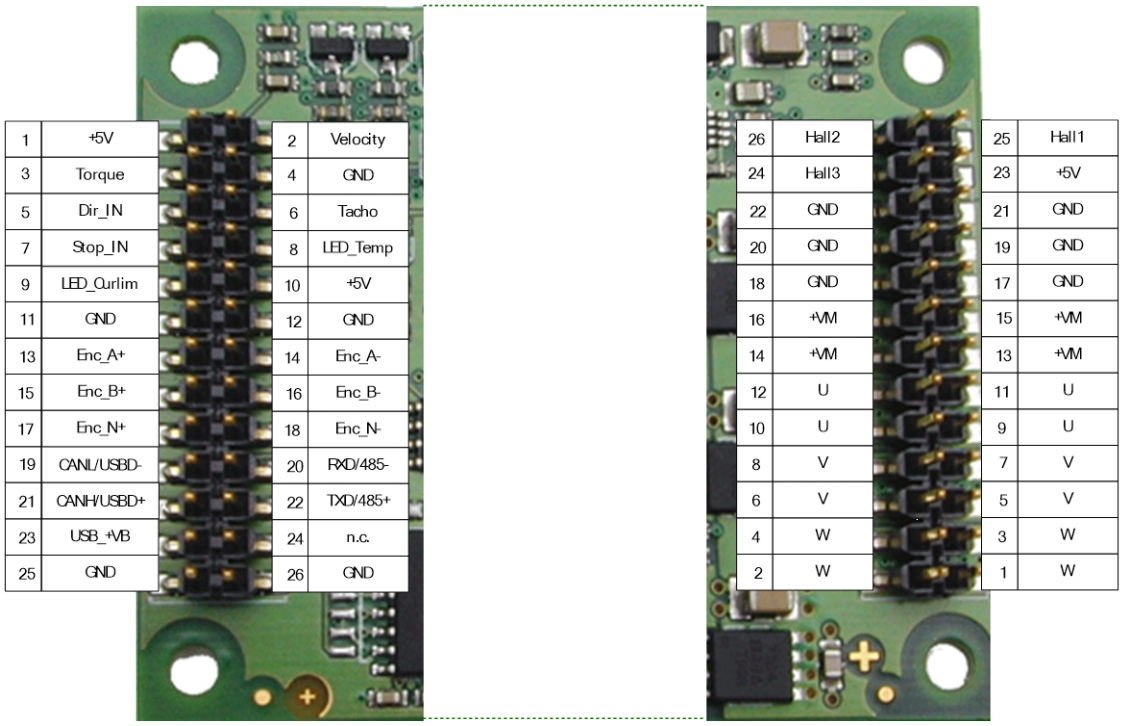



**Figure 3.1: Connectors of the TMCM-1630**

| Domain | Connector type | Mating connector type |
|---|---|---|
| I/Os, interfaces, encoder | TSM-113-03-L-DV-K-A, 2x13 poles, double row, 2.54mm pitch, SMD vertical, Samtec | SSW, SSQ, SSM, BSW, ESW, ESQ, BCS, SLW, CES, HLE , IDSS and IDSD series, Samtec |
| Power, hallFX™, motor | TSM-113-03-L-DV-K-A, 2x13 poles, double row, 2.54mm pitch, SMD vertical, Samtec | SSW, SSQ, SSM, BSW, ESW, ESQ, BCS, SLW, CES, HLE , IDSS and IDSD series, Samtec |

**1. Connect the motor, power supply and hall sensors**

*Since the two connectors of the TMCM-1630 are similar be careful not to connect the module turned around. When powered up this would damage the module. Be sure to place the connectors exactly to their opponents. A deviation of only one pin row can damage the module also.*

*Start with power supply OFF!*

| Pin | Label | Description | Pin | Label | Description |
|---|---|---|---|---|---|
| 1 | W | Motor coil W | 2 | W | Motor coil W |
| 3 | W | Motor coil W | 4 | W | Motor coil W |
| 5 | V | Motor coil V | 6 | V | Motor coil V |
| 7 | V | Motor coil V | 8 | V | Motor coil V |
| 9 | U | Motor coil U | 10 | U | Motor coil U |
| 11 | U | Motor coil U | 12 | U | Motor coil U |
| 13 | VM | Module driver supply voltage | 14 | VM | Module driver supply voltage |
| 15 | VM | Module driver supply voltage | 16 | VM | Module driver supply voltage |
| 17 | GND | Module ground (power supply and signal ground) | 18 | GND | Module ground (power supply and signal ground) |
| 19 | GND | Module ground (power supply and signal ground) | 20 | GND | Module ground (power supply and signal ground) |
| 21 | GND | Module ground (power supply and signal ground) | 22 | GND | Module ground (power supply and signal ground) |
| 23 | +5V | +5V output (100mA max.) for encoder and/or hall sensor supply | 24 | HALL3 | Hall sensor 3 signal input |
| 25 | HALL1 | Hall sensor 1 signal input | 26 | HALL2 | Hall sensor 2 signal input |

**2. Connect the interface, IOs and the encoder as follows:**

*Since the two connectors of the TMCM-1630 are similar be careful not to connect the module turned around. When powered up this would damage the module. Be sure to place the connectors exactly to their opponents. A deviation of only one pin row can damage the module also.*

| Pin | Label | Description | Pin | Label | Description |
|---|---|---|---|---|---|
| 1 | +5V | 5V analog reference as used by the internal DAC.<br>Max. load 0.5mA | 2 | Velocity | Used for velocity control in standalone operation by supplying external 0 - 10V signal |
| 3 | Torque | Used for max. motor current / torque control in standalone operation by supplying external 0-10V signal | 4 | GND | Module ground (power supply and signal ground) |
| 5 | Dir_IN | 5V TTL input. Tie to GND to inverse motor direction, leave open or tie to 5V otherwise. | 6 | Tacho | This pin outputs a tacho impulse, i.e. toggles on each hall sensor change |
| 7 | Stop_IN | Emergency stop. Tie this pin to GND to stop the motor (same as the *Motor OFF* switch on PCB). The motor can be restarted via the interface, or by cycling the power supply | 8 | LED-Temp | 5V TTL output: Toggling with 3Hz when temperature pre-warning threshold is exceeded, high when module shut down due to overtemperature |
| 9 | LED-Curlim | High, when module goes into current limiting mode | 10 | +5V | 5V output as reference for external purpose |
| 11 | GND | GND reference | 12 | GND | GND reference |
| 13 | Enc_A+ | Encoder A+ channel | 14 | Enc_A- | Encoder A- channel |
| 15 | Enc_B+ | Encoder B+ channel | 16 | Enc_B- | Encoder B- channel |

| | | | | | |
|---|---|---|---|---|---|
| 17 | Enc_N+ | Encoder N+ channel | 18 | Enc_N- | Encoder N- channel |
| 19 | CANL/USBD- | CAN low /<br>USB D- bus line | 20 | RXD/<br>485- | RXD signal for RS232 /<br>inverting signal for RS485 |
| 21 | CANH/USBD+ | CAN high /<br>USB D+ bus line | 22 | TXD/<br>485+ | TXD signal for RS232 /<br>non inverting signal for RS485 |
| 23 | USB_+VB | Use to detect availability of attached host system (e.g. PC) | 24 | n.c. | |
| 25 | GND | GND reference | 26 | GND | GND reference |

3. **Switch ON the power supply**
   The power LED is ON now.
   ***If this does not occur, switch power OFF and check your connections as well as the power supply.***

4. **Start the TMCL-IDE software development environment**
   The TMCL-IDE is available on the TechLibCD and on www.trinamic.com.

   **Installing the TMCL-IDE**
   Make sure the COM port you intend to use is not blocked by another program.
   Open TMCL-IDE by clicking ***TMCL.exe***.

   Choose ***Setup*** and ***Options*** and thereafter the ***Connection tab***. Choose ***Type***. The TMCL-IDE shows you which ***Port*** the module uses. Click ***OK***.

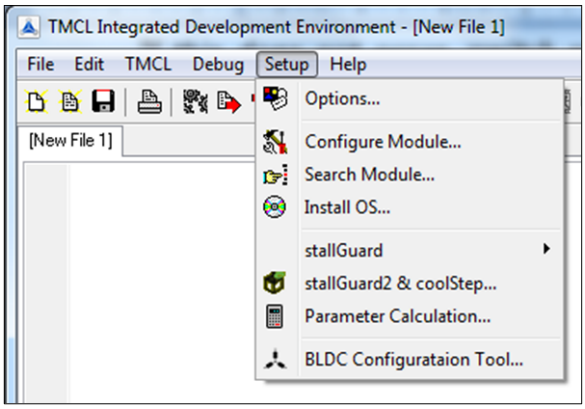



**Figure 3.2: Setup menu**

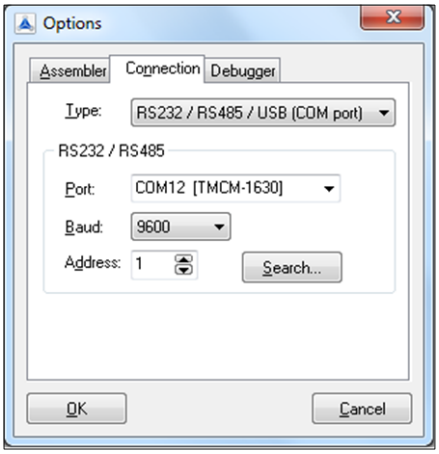
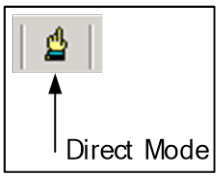



**Figure 3.3: Connection tab of TMCL-IDE**

## 3.2 Operating the Module in Direct Mode

1. Start TMCL ***Direct Mode***.




2. If the communication is established the TMCM-1630 is automatically detected. ***If the module is not detected, please check all points above (cables, interface, power supply, COM port, baud rate).***
3. Issue a command by choosing ***instruction***, ***type*** (if necessary), ***motor***, and ***value*** and click ***execute*** to send it to the module.

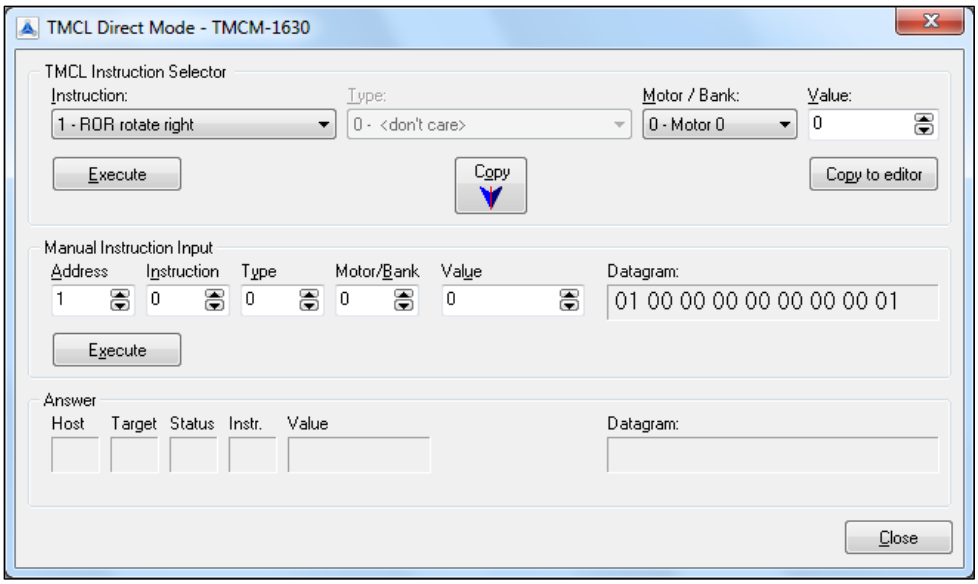



**Figure 3.4: TMCL direct mode window**

Examples:

- ROR rotate right, motor 0, value 500 -> Click *Execute*. The first motor is rotating now.
- MST motor stop, motor 0 -> Click *Execute*. The first motor stops now.

# 4 TMCL and TMCL-IDE

The TMCM-1630 module supports TMCL direct mode (binary commands) and standalone TMCL program execution. You can store up to 2048 TMCL instructions on it.

In direct mode the TMCL communication over USB, CAN, RS232, and RS485 follows a strict master/slave relationship. That is, a host computer (e.g. PC/PLC) acting as the interface bus master will send a command to the module. The TMCL interpreter on it will then interpret this command, do the initialization of the motion controller, read inputs and write outputs or whatever is necessary according to the specified command. As soon as this step has been done, the module will send a reply back over the interface to the bus master. The master should not transfer the next command till then. Normally, the module will just switch to transmission and occupy the bus for a reply, otherwise it will stay in receive mode. It will not send any data over the interface without receiving a command first. This way, any collision on the bus will be avoided when there are more than two nodes connected to a single bus.

The Trinamic Motion Control Language (TMCL) provides a set of structured motion control commands. Every motion control command can be given by a host computer or can be stored on the TMCM-1630 to form programs that run standalone on the module. For this purpose there are not only motion control commands but also commands to control the program structure (like conditional jumps, compare and calculating).

Every command has a binary representation and a mnemonic:

- The binary format is used to send commands from the host to a module in direct mode.
- The mnemonic format is used for easy usage of the commands when developing standalone TMCL applications with the TMCL-IDE (IDE means *Integrated Development Environment*).

There is also a set of configuration variables for the axis and for global parameters which allow individual configuration of nearly every function of a module. This manual gives a detailed description of all TMCL commands and their usage.

## 4.1 Binary Command Format

When commands are sent from a host to a module, the binary format has to be used. Every command consists of a one-byte command field, a one-byte type field, a one-byte motor/bank field and a four-byte value field. So the binary representation of a command always has seven bytes.

When a command is to be sent via RS232, USB or RS485 interface, it has to be enclosed by an address byte at the beginning and a checksum byte at the end. In this case it consists of nine bytes.

**The binary command format for RS232/RS485/USB is structured as follows:**

| Bytes | Meaning |
|---|---|
| 1 | Module address |
| 1 | Command number |
| 1 | Type number |
| 1 | Motor or Bank number |
| 4 | Value (MSB first!) |
| 1 | Checksum |

- When using CAN bus, the first byte (reply address) and the last byte (checksum) are left out.
- Do not send the next command before you have received the reply!

**Checksum calculation**

As mentioned above, the checksum is calculated by adding up all bytes (including the module address byte) using 8-bit addition. Here is an example for the calculation:

- in C:

```
unsigned char i, Checksum;
unsigned char Command[9];

//Set the "Command" array to the desired command
Checksum = Command[0];
for(i=1; i<8; i++)
    Checksum+=Command[i];

Command[8]=Checksum; //insert checksum as last byte of the command
//Now, send the command back to the module
```

## 4.2 Reply Format

Every time a command has been sent to a module, the module sends a reply.

**The reply format for RS232/RS485/USB is structured as follows:**

| Bytes | Meaning |
|---|---|
| 1 | Reply address |
| 1 | Module address |
| 1 | Status (e.g. 100 means *no error*) |
| 1 | Command number |
| 4 | Value (MSB first!) |
| 1 | Checksum |

- The checksum is calculated by adding up all the other bytes using an 8-bit addition.
- When using CAN bus, the first byte (reply address) and the last byte (checksum) are left out.
- Do not send the next command before you have received the reply!

### 4.2.1 Status Codes

The reply contains a status code.

**The status code can have one of the following values:**

| Code | Meaning |
|---|---|
| 100 | Successfully executed, no error |
| 101 | Command loaded into TMCL program EEPROM |
| 1 | Wrong checksum |
| 2 | Invalid command |
| 3 | Wrong type |
| 4 | Invalid value |
| 5 | Configuration EEPROM locked |
| 6 | Command not available |

## 4.3 Standalone Applications

The module is equipped with an EEPROM for storing TMCL applications. You can use the TMCL-IDE for developing standalone TMCL applications. You can load your program down into the EEPROM and then it will run on the module. The TMCL-IDE contains an *editor* and a TMCL *assembler* where the commands can be entered using their mnemonic format. They will be assembled automatically into their binary representations. Afterwards this code can be downloaded into the module to be executed there.

## 4.4 Testing with a Simple TMCL Program

Open the file test2.tmc of the TMCL-IDE. The following source code appears on the screen:

```
//A simple example for using TMCL and TMCL-IDE

        Loop:
          ROL 0, 4000                 //rotate left with 4000 rev/min
          WAIT TICKS, 0, 2000
          ROR 0, 4000                 //rotate right with 4000 rev/min
          WAIT TICKS, 0, 2000
          JA Loop
```

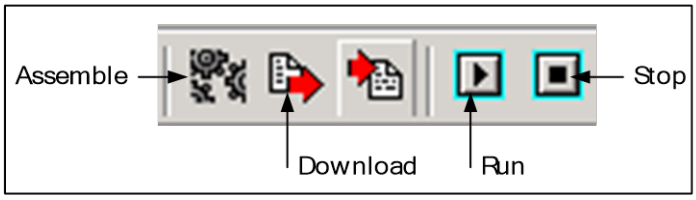



**Figure 4.1: Assemble, download, stop, and run icons of TMCL-IDE**

1. Click on icon ***Assemble*** to convert the example into binary code.
2. Then download the program to the TMCM-1630 module via the icon ***Download***.
3. Press icon ***Run***. The desired program will be executed.
4. Click ***Stop*** button to stop the program.

For further information about the TMCL-IDE and TMCL programming techniques please refer to the TMCL-IDE User Manual on TRINAMICs website.

TRINAMIC offers two software tools for BLDC applications: the TMCM-BLDC and the BLDC tool of the TMCL-IDE. Whereas the TMCM-BLDC is used for testing different configurations in all modes of operation the TMCL-IDE is mainly designed for conceiving programs and firmware updates. New versions of the TMCM-BLDC and the TMCL-IDE can be downloaded free of charge from the TRINAMIC website (http://www.trinamic.com).

# 4.5 TMCL Command Overview

The following section provides a short overview of the TMCL commands supported by the TMCM-1630.

## 4.5.1 Motion Commands

These commands control the motion of the motor. They are the most important commands and can be used in direct mode or in standalone mode.

| Mnemonic | Command number | Meaning |
|---|---|---|
| ROL | 2 | Rotate left |
| ROR | 1 | Rotate right |
| MVP | 4 | Move to position |
| MST | 3 | Motor stop |

## 4.5.2 Parameter Commands

These commands are used to set, read and store axis parameters or global parameters. Axis parameters can be set independently for the axis, whereas global parameters control the behavior of the module itself. These commands can also be used in direct mode and in standalone mode.

| Mnemonic | Command number | Meaning |
|---|---|---|
| SAP | 5 | Set axis parameter |
| GAP | 6 | Get axis parameter |
| STAP | 7 | Store axis parameter into EEPROM |
| RSAP | 8 | Restore axis parameter from EEPROM |
| SGP | 9 | Set global parameter |
| GGP | 10 | Get global parameter |
| STGP | 11 | Store global parameter into EEPROM |
| RSGP | 12 | Restore global parameter from EEPROM |

## 4.5.3 Control Commands

These commands are used to control the program flow (loops, conditions, jumps etc.). It does not make sense to use them in direct mode. They are intended for standalone mode only.

| Mnemonic | Command number | Meaning |
|---|---|---|
| JA | 22 | Jump always |
| JC | 21 | Jump conditional |
| COMP | 20 | Compare accumulator with constant value |
| CSUB | 23 | Call subroutine |
| RSUB | 24 | Return from subroutine |
| WAIT | 27 | Wait for a specified event |
| STOP | 28 | End of a TMCL program |

## 4.5.4 I/O Port Commands

These commands control the external I/O ports and can be used in direct mode and in standalone mode.

| Mnemonic | Command number | Meaning |
|---|---|---|
| SIO | 14 | Set output |
| GIO | 15 | Get input |

### 4.5.5 Calculation Commands

These commands are intended to be used for calculations within TMCL applications in standalone mode, only. For calculating purposes there are an accumulator (or accu or A register) and an X register. When executed in a TMCL program (in standalone mode), all TMCL commands that read a value store the result in the accumulator. The X register can be used as an additional memory when doing calculations. It can be loaded from the accumulator.

| Mnemonic | Command number | Meaning |
|---|---|---|
| CALC | 19 | Calculate using the accumulator and a constant value |
| CALCX | 33 | Calculate using the accumulator and the X register |
| AAP | 34 | Copy accumulator to an axis parameter |
| AGP | 35 | Copy accumulator to a global parameter |

**MIXING STANDALONE PROGRAM EXECUTION AND DIRECT MODE**

It is possible to use some commands in direct mode while a standalone program is active. When a command which reads out a value is executed (direct mode) the accumulator will not be affected. While a TMCL program is running standalone on the module, a host can still send commands like GAP and GGP to it (e.g. to query the actual position of the motor) without affecting the flow of the TMCL program running standalone on the module.

# 4.6 Commands

The module specific commands are explained in more detail on the following pages. They are listed according to their command number.

## 4.6.1 ROR (rotate right)

The motor will be instructed to rotate with a specified velocity in *right* direction (increasing the position counter).

**Internal function:** First, velocity mode is selected. Then, the velocity value is transferred to axis parameter #2 (*target velocity*).

**Related commands:** ROL, MST, SAP, GAP

**Mnemonic:** ROR 0, <velocity>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE <velocity> |
|---|---|---|---|
| 1 | don't care | 0 | -200000... +200000 |

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 1 | don't care |

**Example:**
Rotate right, velocity = 350
*Mnemonic:* ROR 0, 350

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $01 | $00 | $00 | $00 | $00 | $01 | $5e |

### 4.6.2 ROL (rotate left)

The motor will be instructed to rotate with a specified velocity (opposite direction compared to ROR, decreasing the position counter).

**Internal function:** First, velocity mode is selected. Then, the velocity value is transferred to axis parameter #2 (*target velocity*).

**Related commands:** ROR, MST, SAP, GAP

**Mnemonic:** ROL 0, <velocity>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE <velocity> |
|---|---|---|---|
| 2 | don't care | 0 | -200000... +200000 |

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 2 | don't care |

**Example:**

Rotate left, velocity = 1200
*Mnemonic:* ROL 0, 1200

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $02 | $00 | $00 | $00 | $00 | $04 | $b0 |

### 4.6.3 MST (motor stop)

The motor will be instructed to stop.

**Internal function:** The axis parameter *target velocity* is set to zero.

**Related commands:** ROL, ROR, SAP, GAP

**Mnemonic:** MST 0

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 3 | don't care | 0 | don't care |

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 3 | don't care |

**Example:**

Stop motor
*Mnemonic:* MST 0

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $03 | $00 | $00 | $00 | $00 | $00 | $00 |

### 4.6.4 MVP (move to position)

The motor will be instructed to move to a specified relative or absolute position. It uses the acceleration/deceleration ramp and the positioning speed programmed into the unit. This command is non-blocking (like all commands). A reply will be sent immediately after command interpretation. Further commands may follow without waiting for the motor reaching its end position. The maximum velocity and acceleration are defined by axis parameters #4 and #11.

**TWO OPERATION TYPES ARE AVAILABLE:**

- Moving to an absolute position in the range from -2147483648... +2147483647.
- Starting a relative movement by means of an offset to the actual position. In this case, the new resulting position value must not exceed the above mentioned limits, too.

**Internal function:** A new position value is transferred to the axis parameter #0 *target position*.

**Related commands:** SAP, GAP, and MST

**Mnemonic:** MVP <ABS|REL>, 0, <position|offset value>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 4 | 0 ABS – absolute | 0 | <position> -2147483648... +2147483647 |
| | 1 REL – relative | 0 | <offset> -2147483648... +2147483647 |

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 4 | don't care |

**Example MVP ABS:**

Move motor to (absolute) position 9000
*Mnemonic:* MVP ABS, 0, 9000

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $04 | $00 | $00 | $00 | $00 | $23 | $28 |

**Example MVP REL:**

Move motor from current position 1000 steps backward (move relative -1000)
*Mnemonic:* MVP REL, 0, -1000

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $00 | $04 | $01 | $00 | $ff | $ff | $fc | $18 |

### 4.6.5 SAP (set axis parameter)

Most of the motion control parameters of the module can be specified by using the SAP command. The settings will be stored in SRAM and therefore are volatile. Thus, information will be lost after power off. ***Please use command STAP (store axis parameter) in order to store any setting permanently.***

**Related commands:** GAP, STAP, and RSAP

**Mnemonic:** SAP <parameter number>, 0, <value>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 5 | <parameter number> | 0 | <value> |

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 5 | don't care |

A list of all parameters which can be used for the SAP command is shown in section 5.

**Example:**

Set the absolute maximum current to 2000mA
*Mnemonic:* SAP 6, 0, 2000

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $05 | $06 | $00 | $00 | $00 | $07 | $D0 |

### 4.6.6 GAP (get axis parameter)

Most parameters of the TMCM-1630 can be adjusted individually. They can be read out using the GAP command.

**Related commands:** SAP, STAP, and RSAP

**Mnemonic:** GAP <parameter number>, 0

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 6 | <parameter number> | 0 | don't care |

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 6 | don't care |

A list of all parameters which can be used for the GAP command is shown in section 5.

**Example:**

Get the actual position of motor
*Mnemonic:* GAP 1, 0

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $06 | $01 | $00 | $00 | $00 | $00 | $00 |

*Reply:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Host-address | Target-address | Status | Instruction | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $00 | $01 | $64 | $06 | $00 | $00 | $02 | $c7 |

### 4.6.7 STAP (store axis parameter)

The STAP command stores an axis parameter previously set with a *Set Axis Parameter command (SAP)* permanently. Most parameters are automatically restored after power up.

**Internal function:** An axis parameter value stored in SRAM will be transferred to EEPROM and loaded from EEPORM after next power up.

**Related commands:** SAP, RSAP, and GAP

**Mnemonic:** STAP <parameter number>, 0

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 7 | <parameter number> | 0 | don't care* |

*** The value operand of this function has no effect. Instead, the currently used value (e.g. selected by SAP) is saved.**

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 7 | don't care |

A list of all parameters which can be used for the STAP command is shown in section 5.

**Example:**

Store the maximum speed
*Mnemonic:* STAP 4, 0

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $07 | $04 | $00 | $00 | $00 | $00 | $00 |

***Note: The STAP command will not have any effect when the configuration EEPROM is locked. The error code 5 (configuration EEPROM locked) will be returned in this case.***

### 4.6.8 RSAP (restore axis parameter)

For all configuration related axis parameters non-volatile memory locations are provided. By default, most parameters are automatically restored after power up. A single parameter that has been changed before can be reset by this instruction also.

**Internal function:** The specified parameter is copied from the configuration EEPROM memory to its RAM location.

**Related commands:** SAP, STAP, and GAP

**Mnemonic:** RSAP <parameter number>, 0

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 8 | <parameter number> | 0 | don't care |

**Reply in direct mode:**

| STATUS | COMMAND | VALUE |
|---|---|---|
| 100 – OK | 8 | don't care |

A list of all parameters which can be used for the RSAP command is shown in section 5.

**Example:**

Restore the maximum current
*Mnemonic:* RSAP 6, 0

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $08 | $06 | $00 | $00 | $00 | $00 | $00 |

### 4.6.9 SGP (set global parameter)

Global parameters are related to the host interface, peripherals or other application specific variables. The different groups of these parameters are organized in *banks* to allow a larger total number for future products. Currently, bank 0 is used for global parameters and bank 2 is intended for user variables.

**Related commands:** GGP, STGP, RSGP

**Mnemonic:** SGP <parameter number>, <bank number>, <value>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 9 | <parameter number> | <bank number> | <value> |

**Reply in direct mode:**

| STATUS | VALUE |
|---|---|
| 100 – OK | don't care |

A list of all parameters which can be used for the SGP command is shown in section 6.

**Example:**

Set variable 0 at bank 2 to 100
*Mnemonic:* SGP, 0, 2, 100

**Binary:**

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $09 | $00 | $02 | $00 | $00 | $00 | $64 |

## 4.6.10 GGP (get global parameter)

All global parameters can be read with this function.

**Related commands:** SGP, STGP, RSGP

**Mnemonic:** GGP <parameter number>, <bank number>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 10 | <parameter number> | <bank number> | don't care |

**Reply in direct mode:**

| STATUS | VALUE |
|---|---|
| 100 – OK | <value> |

A list of all parameters which can be used for the GGP command is shown in section 6.

**Example:**

Get variable 0 from bank 2
*Mnemonic:* GGP, 0, 2

**Binary:**

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $0a | $00 | $02 | $00 | $00 | $00 | $00 |

## 4.6.11 STGP (store global parameter)

Some global parameters are located in RAM memory, so modifications are lost at power down. This instruction copies a value from its RAM location to the configuration EEPROM and enables permanent storing. Most parameters are automatically restored after power up.

**Related commands:** SGP, GGP, RSGP

**Mnemonic:** STGP <parameter number>, <bank number>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 11 | <parameter number> | <bank number> | don't care |

**Reply in direct mode:**

| STATUS | VALUE |
|---|---|
| 100 – OK | don't care |

A list of all parameters which can be used for the STGP command is shown in section 6.

**Example:**

Copy variable 0 at bank 2 to the configuration EEPROM
*Mnemonic:* STGP, 0, 2

**Binary:**

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $0b | $00 | $02 | $00 | $00 | $00 | $00 |

## 4.6.12 RSGP (restore global parameter)

This instruction copies a value from the configuration EEPROM to its RAM location and so recovers the permanently stored value of a RAM-located parameter. Most parameters are automatically restored after power up.

**Related commands:** SGP, GGP, STGP

**Mnemonic:** RSGP <parameter number>, <bank number>

**Binary representation:**

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 12 | <parameter number> | <bank number> | don't care |

**Reply in direct mode:**

| STATUS | VALUE |
|---|---|
| 100 – OK | don't care |

A list of all parameters which can be used for the RSGP command is shown in section 6.

**Example:**

Copy variable 0 at bank 2 from the configuration EEPROM to the RAM location
*Mnemonic:* RSGP, 0, 2

**Binary:**

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $0c | $00 | $02 | $00 | $00 | $00 | $00 |

## 4.6.13 SIO (set output) and GIO (get input / output)

The TMCM-1630 provides two commands for dealing with inputs and outputs:

- ***SIO*** sets the status of the general digital output either to low (0) or to high (1).
- With ***GIO*** the status of all general purpose inputs of the module can be read out. The command reads out a digital or analogue input port. Digital lines will read 0 and 1, while the ADC channel delivers 12 bit in the range of 0... 4095.

**CORRELATION BETWEEN I/OS AND BANKS**

| Inputs/ Outputs | Bank | Description |
|---|---|---|
| Digital inputs | Bank 0 | Digital inputs are accessed in bank 0. |
| Analogue inputs | Bank 1 | Analog inputs are accessed in bank 1. |
| Digital outputs | Bank 2 | The states of the OUT lines (that have been set by SIO commands) can be read back using bank 2. |

### 4.6.13.1 SIO (set output)

*Bank 2 is used for setting the status of the general digital output either to low (0) or to high (1).*

**Internal function:** the passed value is transferred to the specified output line.

**Related commands:** GIO, WAIT

**Mnemonic:** SIO <port number>, <bank number>, <value>

**Binary representation:**

| INSTRUCTION NO. | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 14 | <port number> | <bank number><br>2 | <value><br>0/1 |

**Reply structure:**

| STATUS | VALUE |
|---|---|
| 100 – OK | don't care |

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $0e | $07 | $02 | $00 | $00 | $00 | $01 |

### 4.6.13.2 GIO (get input/output)

GIO can be used in direct mode or in standalone mode.

**GIO IN STANDALONE MODE**

In standalone mode the requested value is copied to the accumulator (accu) for further processing purposes such as conditioned jumps.

**GIO IN DIRECT MODE**

In direct mode the value is output in the value field of the reply without affecting the accumulator. The actual status of a digital output line can also be read.

**Internal function:** the specified line is read.

**Related commands:** SIO, WAIT

**Mnemonic:** GIO <port number>, <bank number>

**Binary representation:**

| INSTRUCTION NO. | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 15 | <port number> | <bank number> | don't care |

**Reply in direct mode:**

| STATUS | VALUE |
|---|---|
| 100 – OK | <status of the port> |

*Binary:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $0f | $00 | $01 | $00 | $00 | $00 | $00 |

*Reply:*

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Host-address | Target-address | Status | Instruction | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $02 | $01 | $64 | $0f | $00 | $00 | $01 | $2e |

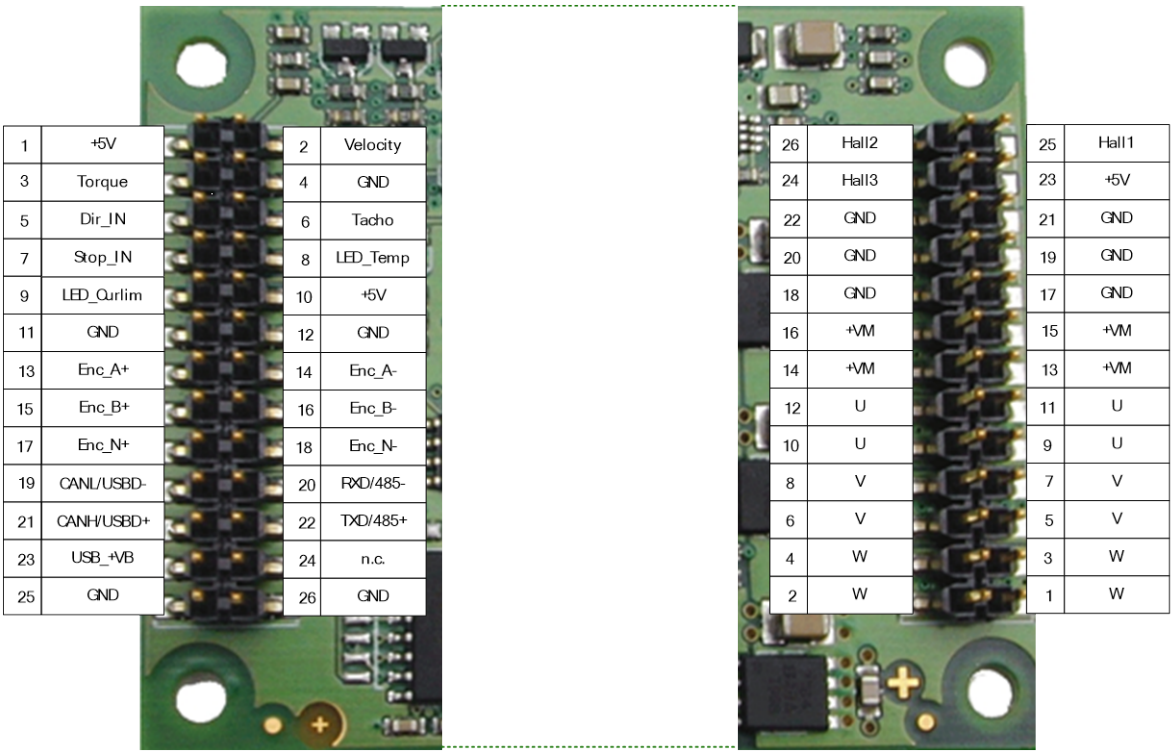



**Figure 4.2 Connector of TMCM-1630**

### PROVIDED SIO AND GIO COMMANDS

| Pin | Digital | Analog | GIO <port>, <bank> | SIO <port>, <bank>, <value> | Value range |
|---|---|---|---|---|---|
| 2 | - | x | GIO 0, 1 (velocity) | - | 0… 4095 |
| 3 | - | x | GIO 1, 1 (torque) | - | 0… 4095 |
| 5 | x | - | GIO 0, 0 (DIR_IN) | - | 0/1 |
| 6 | x | - | GIO 0, 2 (tacho) | SIO 0, 2, <value> | 0/1 |
| 7 | x | - | GIO 1, 0 (STOP_IN) | - | 0/1 |

**THE FOLLOWING PROGRAM WILL SHOW THE STATES OF THE INPUT LINES ON THE OUTPUT LINES:**

```
Loop: GIO 255, 0
      SIO 255, 2,-1
      JA Loop
```

## 4.6.14 CALC (calculate)

A value in the accumulator variable, previously read by a function such as GAP (get axis parameter), can be modified with this instruction. Nine different arithmetic functions can be chosen and one constant operand value must be specified. The result is written back to the accumulator, for further processing like comparisons or data transfer.

**Related commands:** CALCX, COMP, JC, AAP, AGP, GAP, GGP, GIO

**Mnemonic:** CALC <op>, <value>

Binary representation:

| COMMAND | TYPE <op> | MOT/BANK | VALUE |
|---|---|---|---|
| 19 | 0 ADD – add to accu<br>1 SUB – subtract from accu<br>2 MUL – multiply accu by<br>3 DIV – divide accu by<br>4 MOD – modulo divide by<br>5 AND – logical and accu with<br>6 OR – logical or accu with<br>7 XOR – logical exor accu with<br>8 NOT – logical invert accu<br>9 LOAD – load operand to accu | don't care | <operand> |

**Example:**
Multiply accu by -5000
*Mnemonic:* CALC MUL, -5000

Binary:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $13 | $02 | $00 | $FF | $FF | $EC | $78 |

## 4.6.15 COMP (compare)

The specified number is compared to the value in the accumulator register. The result of the comparison can be used for example by the conditional jump (JC) instruction. This command is intended for use in standalone operation, only. The host address and the reply are required to take the instruction to the TMCL program memory while the TMCL program downloads. It does not make sense to use this command in direct mode.

**Internal function:** The specified value is compared to the internal *accumulator*, which holds the value of a preceding *get* or calculate instruction (see GAP/GGP/CALC/CALCX). The internal arithmetic status flags are set according to the comparison result.

**Related commands:** JC (jump conditional), GAP, GGP, CALC, CALCX

**Mnemonic:** COMP <value>

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 20 | don't care | don't care | <comparison value> |

**Example:**

Jump to the address given by the label when the position of the motor #0 is greater or equal to 1000.

```
GAP 1, 0, 0     //get axis parameter, type: no. 1 (actual position), motor: 0, value: 0 don't care
COMP 1000       //compare actual value to 1000
JC GE, Label    //jump, type: 5 greater/equal, the label must be defined somewhere else in the
                program
```

Binary format of the COMP 1000 command:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $14 | $00 | $00 | $00 | $00 | $03 | $e8 |

## 4.6.16 JC (jump conditional)

The JC instruction enables a conditional jump to a fixed address in the TMCL program memory, if the specified condition is met. The conditions refer to the result of a preceding comparison. This function is for standalone operation only. The host address and the reply are required to take the instruction to the TMCL program memory while the TMCL program downloads. It is not possible to use this command in direct mode.

**Internal function:** The TMCL program counter is set to the passed value if the arithmetic status flags are in the appropriate state(s).

**Related commands:** JA, COMP, WAIT

**Mnemonic:** JC <condition>, <label>
where <condition>=ZE|NZ|EQ|NE|GT|GE|LT|LE|ETO|EAL

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 21 | 0 ZE - zero<br>1 NZ - not zero<br>2 EQ - equal<br>3 NE - not equal<br>4 GT - greater<br>5 GE - greater/equal<br>6 LT - lower<br>7 LE - lower/equal<br>8 ETO - time out error<br>9 EAL - external alarm | don't care | <jump address> |

**Example:**

Jump to address given by the label when the position of the motor is greater than or equal to 1000.

```
GAP 1, 0, 0      //get axis parameter, type: no. 1 (actual position), motor: 0, value: 0 don't care
COMP 1000        //compare actual value to 1000
JC GE, Label     //jump, type: 5 greater/equal
...
...
Label: ROL 0, 1000
```

Binary format of JC GE, Label when Label is at address 10:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $15 | $05 | $00 | $00 | $00 | $00 | $0a |

### 4.6.17 JA (jump always)

Jump to a fixed address in the TMCL program memory. This command is intended for standalone operation, only. The host address and the reply are required to take the instruction to the TMCL program memory while the TMCL program downloads. This command cannot be used in direct mode.

**Internal function:** The TMCL program counter is set to the passed value.

**Related commands:** JC, WAIT, CSUB

**Mnemonic:** JA <Label>

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 22 | don't care | don't care | <jump address> |

**Example:**

An infinite loop in TMCL

```
Loop:  MVP ABS, 0, 10000
       WAIT POS, 0, 0
       MVP ABS, 0, 0
       WAIT POS, 0, 0
       JA Loop          //Jump to the label Loop
```

Binary format of JA Loop assuming that the label Loop is at address 20:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| **Function** | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| **Value (hex)** | $01 | $16 | $00 | $00 | $00 | $00 | $00 | $14 |

## 4.6.18 CSUB (call subroutine)

For implementing subroutines there are two commands:

- ***CSUB*** calls a subroutine in the TMCL program memory. It is intended for standalone operation, only. The host address and the reply are required to take the instruction to the TMCL program memory while the TMCL program downloads. *This command cannot be used in direct mode.*
- ***RSUB*** is used for returning from a subroutine to the next command behind the CSUB command.

**Example:** Call a subroutine

```
Loop:  MVP ABS, 0, 10000
       CSUB SubW     //Save program counter and jump to label SubW (see below)
       MVP ABS, 0, 0
       JA Loop

SubW:  WAIT POS, 0, 0
       WAIT TICKS, 0, 50
       RSUB          //Continue with the command following the CSUB command (in this
                     example: MVP ABS).
```

### 4.6.18.1 CSUB (call subroutine)

**Internal function:** The actual TMCL program counter value is saved to an internal stack, afterwards overwritten with the passed value. The number of entries in the internal stack is limited to 8. This also limits nesting of subroutine calls to 8. The command will be ignored if there is no more stack space left.

**Related commands:** RSUB, JA

**Mnemonic:** CSUB <Label>

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 23 | don't care | don't care | <subroutine address> |

Binary format of the CSUB SubW command assuming that the label SubW is at address 100:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $17 | $00 | $00 | $00 | $00 | $00 | $64 |

### 4.6.18.2 RSUB (return from subroutine)

**Internal function:** The TMCL program counter is set to the last value of the stack. The command will be ignored if the stack is empty.

**Related command:** CSUB

**Mnemonic:** RSUB

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 24 | don't care | don't care | don't care |

Binary format of RSUB:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $18 | $00 | $00 | $00 | $00 | $00 | $00 |

## 4.6.19 WAIT (wait for an event to occur)

This instruction interrupts the execution of the TMCL program until the specified condition is met. This command is intended for standalone operation only. The host address and the reply are only used to take the instruction to the TMCL program memory while the TMCL program downloads. This command is not to be used in direct mode.

**THERE ARE DIFFERENT WAIT CONDITIONS THAT CAN BE USED:**

TICKS: Wait until the number of timer ticks specified by the <ticks> parameter has been reached.
POS: Wait until the target position of the motor specified by the <motor> parameter has been reached. An optional timeout value (0 for no timeout) must be specified by the <ticks> parameter.

The timeout flag (ETO) will be set after a timeout limit has been reached. You can then use a JC ETO command to check for such errors or clear the error using the CLE command.

**Internal function:** The TMCL program counter is held until the specified condition is met.

Related commands: JC, CLE

**Mnemonic:** WAIT <condition>, <motor number>, <ticks>
where <condition> is TICKS|POS

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 27 | 0 TICKS - timer ticks* | don't care | <no. of ticks*> |
| | 1 POS - target position reached | <motor number><br>0 | <no. of ticks* for timeout>,<br>0 for no timeout |

* One tick is 10msec (in standard firmware).

Example:
Wait for motor to reach its target position, without timeout
*Mnemonic:* WAIT POS, 0, 0

Binary:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $1b | $01 | $01 | $00 | $00 | $00 | $00 |

## 4.6.20 STOP (stop TMCL program execution)

This function stops executing a TMCL program. The host address and the reply are only used to transfer the instruction to the TMCL program memory.

Every standalone TMCL program needs the STOP command at its end. It is not to be used in direct mode.

**Internal function:** TMCL instruction fetching is stopped.

**Related commands:** none

**Mnemonic:** STOP

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 28 | don't care | don't care | don't care |

**Example:**

Stop TMCL execution
*Mnemonic*: STOP

Binary:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $1c | $00 | $00 | $00 | $00 | $00 | $00 |

## 4.6.21 CALCX (calculate using the X register)

This instruction is very similar to CALC, but the second operand comes from the X register. The X register can be loaded with the LOAD or the SWAP type of this instruction. The result is written back to the accumulator for further processing like comparisons or data transfer.

**Related commands:** CALC, COMP, JC, AAP, AGP

**Mnemonic:** CALCX <operation>

Binary representation:

| COMMAND | TYPE <operation> | MOT/BANK | VALUE |
|---|---|---|---|
| 33 | 0 ADD – add X register to accu<br>1 SUB – subtract X register from accu<br>2 MUL – multiply accu by X register<br>3 DIV – divide accu by X-register<br>4 MOD – modulo divide accu by x-register<br>5 AND – logical and accu with X-register<br>6 OR – logical or accu with X-register<br>7 XOR – logical exor accu with X-register<br>8 NOT – logical invert X-register<br>9 LOAD – load accu to X-register<br>10 SWAP – swap accu with X-register | don't care | don't care |

**Example:**

Multiply accu by X-register
*Mnemonic:* CALCX MUL

Binary:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $21 | $02 | $00 | $00 | $00 | $00 | $00 |

## 4.6.22 AAP (accumulator to axis parameter)

The content of the accumulator register is transferred to the specified axis parameter. For practical use, the accumulator has to be loaded e.g. by a preceding GAP instruction. The accumulator may have been modified by the CALC or CALCX (calculate) instruction.

**Related commands:** AGP, SAP, GAP, SGP, GGP, CALC, CALCX

**Mnemonic:** AAP <parameter number>, 0

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 34 | <parameter number> | 0 | <don't care> |

Reply in direct mode:

| STATUS | VALUE |
|---|---|
| 100 – OK | don't care |

See chapter 5 for a complete list of axis parameters.

**Example:**

Positioning a motor by a potentiometer connected to analogue input #0:

```
Start:  GIO 0, 1        // get value of analogue input line 0
        CALC MUL, 4     // multiply by 4
        AAP 0, 0        // transfer result to target position of motor 0
        JA Start        // jump back to start
```

Binary format of the AAP 0, 0 command:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $22 | $00 | $00 | $00 | $00 | $00 | $00 |

## 4.6.23 AGP (accumulator to global parameter)

The content of the accumulator register is transferred to the specified global parameter. For practical use, the accumulator has to be loaded e.g. by a preceding GAP instruction. The accumulator may have been modified by the CALC or CALCX (calculate) instruction.

- Note that the global parameters in bank 0 are mostly EEPROM-only and thus should not be modified automatically by a standalone application.
- See chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** for a complete list of global parameters.

**Related commands:** AAP, SGP, GGP, SAP, GAP

**Mnemonic:** AGP <parameter number>, <bank number>

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 35 | <parameter number> | <bank number> | don't care |

Reply in direct mode:

| STATUS | VALUE |
|---|---|
| 100 – OK | don't care |

**Example:**

Copy accumulator to TMCL user variable #3
*Mnemonic:* AGP 3, 2

Binary:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Instruction Number | Type | Motor/ Bank | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $01 | $23 | $03 | $02 | $00 | $00 | $00 | $00 |

## 4.6.24 Customer Specific TMCL Command Extension (user functions 0… 7)

The user definable functions UF0… UF7 are predefined functions without topic for user specific purposes. A user function UF command uses three parameters. Please contact TRINAMIC for a customer specific programming.

**Internal function:** Call user specific functions implemented in *C* by TRINAMIC.

**Related commands:** none

**Mnemonic:** UF0… UF7 <parameter number>

Binary representation:

| COMMAND | TYPE | MOT/BANK | VALUE |
|---|---|---|---|
| 64… 71 | user defined | user defined | user defined |

Reply in direct mode:

| Byte Index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Function | Target-address | Target-address | Status | Instruction | Operand Byte3 | Operand Byte2 | Operand Byte1 | Operand Byte0 |
| Value (hex) | $02 | $01 | user defined | 64… 71 | user defined | user defined | user defined | user defined |

## 4.6.25 Command 136 – Get Firmware Version

Command 136 is used for reading out the module type and firmware version as a string or in binary format. (*Motor/Bank* and *Value* are ignored.)

*Other control functions can be used with axis parameters.*

| Command | Type | Parameter | Description | Access |
|---|---|---|---|---|
| 136 | 0 – string<br>1 – binary | Firmware version | Get the module type and firmware revision as a string or in binary format. (*Motor/Bank* and *Value* are ignored.) | read |

**TYPE SET TO 0 - REPLY AS A STRING:**

| Byte index | Contents |
|---|---|
| 1 | Host Address |
| 2… 9 | Version string (8 characters, e.g. 1630V202) |

*There is no checksum in this reply format!*

**TYPE SET TO 1 - VERSION NUMBER IN BINARY FORMAT:**

The version number is output in the *value* field.

| Byte index in value field | Contents |
|---|---|
| 1 | Version number, low byte |
| 2 | Version number, high byte |
| 3 | Type number, low byte |
| 4 | Type number, high byte |

# 5 Axis Parameter Overview (SAP, GAP, STAP, RSAP, AAP)

The following section describes all axis parameters that can be used with the SAP, GAP, STAP and RSAP commands.

**MEANING OF THE LETTERS IN COLUMN *ACCESS*:**

| Access type | Related command(s) | Description |
|---|---|---|
| R | GAP | Parameter readable |
| W | SAP, AAP | Parameter writable |
| E | STAP, RSAP | Parameter automatically restored from EEPROM after reset or power-on. These parameters can be stored permanently in EEPROM using STAP command and also explicitly restored (copied back from EEPROM into RAM) using RSAP. |

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 0 | Target position | The target position of a currently executed ramp. | -2147483648... +2147483647 | RW |
| 1 | Actual position | Set/get the position counter without moving the motor. | -2147483648... +2147483647 | RW |
| 2 | Target speed | Set/get the desired target velocity. | -200000... +200000 [rpm] | RW |
| 3 | Actual speed | The actual velocity of the motor. | -2147483648... +2147483647 [rpm] | R |
| 4 | Max. absolute ramp velocity | The maximum velocity used for velocity ramp in velocity mode and positioning mode. Set this value to a realistic velocity which the motor can reach! | 0... +200000 [rpm] | RWE |
| 6 | Max current | Set/get the max allowed motor current.<br>*This value can be temporarily exceeded marginal due to the operation of the current regulator. | 0... +20000 [mA] | RWE |
| 7 | MVP Target reached velocity | Maximum velocity at which end position can be set. Prevents issuing of end position when the target is passed at high velocity. | 0... +200000 [rpm] | RWE |
| 9 | Motor halted velocity | If the actual speed is below this value the motor halted flag will be set. | 0 +200000 [rpm] | RWE |
| 10 | MVP target reached distance | Maximum distance at which the position end flag is set. | 0... +100000 | RWE |
| 11 | Acceleration | Acceleration parameter for ROL, ROR, and the velocity ramp of MVP. | 0... +100000 [RPM/s] | RWE |
| 13 | Ramp generator speed | The actual speed of the velocity ramp used for positioning and velocity mode. | -2147483648... +2147483647 [rpm] | R |
| 25 | Thermal winding time constant | Thermal winding time constant for the used motor. Used for $I^2t$ monitoring. | 0... +4294967295 [ms] | RWE |
| 26 | $I^2t$ limit | An actual $I^2t$ sum that exceeds this limit leads to increasing the $I^2t$ exceed counter. | 0... +4294967295 | RWE |
| 27 | $I^2t$ sum | Actual sum of the $I^2t$ monitor. | 0... +4294967295 | R |
| 28 | $I^2t$ exceed counter | Counts how often an $I^2t$ sum was higher than the $I^2t$ limit. | 0... +4294967295 | RWE |
| 29 | Clear $I^2t$ exceeded flag | Clear the flag that indicates that the $I^2t$ sum has exceeded the $I^2t$ limit. | (ignored) | W |
| 30 | Minute counter | Counts the module operational time in minutes. | 0... +4294967295 [min] | RWE |

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 31 | BLDC re-initialization | Restart the timer and initialize encoder. | (ignored) | W |
| 133 | PID regulation loop delay | Delay of the position and velocity regulator | 0… +10 [ms] | RWE |
| 134 | Current regulation loop delay | Delay of the PID current regulator. | 0… +10 [50µs] | RWE |
| 146 | Activate ramp | 1: Activate velocity ramp generator for position and velocity mode. (Allows usage of acceleration and positioning velocity for MVP command.) | 0/1 | RWE |
| 150 | Actual motor current | Get actual motor current. | -2147483648… +2147483647 [mA] | R |
| 151 | Actual voltage | Actual supply voltage. | 0… +4294967295 | R |
| 152 | Actual driver temperature | Actual temperature of the motor driver. | 0… +4294967295 | R |
| 155 | Target current | Get desired target current or set target current to activate current regulation mode. (+= turn motor in right direction; -= turn motor in left direction) | -20000… +20000 [mA] | RW |
| 156 | Error/Status flags | Bit 0: Overcurrent flag. This flag is set if the max. current limit is exceeded.<br>Bit 1: Undervoltage flag. This flag is set if supply voltage is too low for motor operation.<br>Bit 2: Overvoltage flag. This flag is set if the motor becomes switched off due to overvoltage.<br>Bit 3: Overtemperature flag. This flag is set if overtemperature limit is exceeded.<br>Bit 4: Motor halted flag. This flag is set if motor has been switched off.<br>Bit 5: Hall error flag. This flag is set upon a hall error.<br>Bit 6: TMC603 error flag<br>Bit 7: unused<br>Bit 8: unused<br>Bit 9: Velocity mode active flag<br>Bit 10: Position mode active flag.<br>Bit 11: Torque mode active flag.<br>Bit 12: unused<br>Bit 13: unused<br>Bit 14: Position end flag. This flag is set if the motor has been stopped at the target position.<br>Bit 15: unused<br>Bit 16: unused<br>Bit 17: $I^2t$ exceeded flag. This flag is set if the $I^2t$ sum exceeded the $I^2t$ limit of the motor. (reset by SAP 29 after the time specified by the $I^2t$ thermal winding time constant)<br><br>*Flag 0 to 15 are automatically reset. Only flag 17 must be cleared manually.* | 0…+4294967295 | R |
| 159 | Commutation mode | 6: FOC based on hall sensor<br>7: FOC based on encoder<br>8: FOC controlled | 6, 7, 8 | RWE |
| 161 | Encoder set NULL | 1: set position counter to zero at next N channel event. | 0/1 | RWE |
| 162 | Switch set NULL | 1: set position counter to zero at next switch event. | 0/1 | RWE |

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 163 | Encoder clear set NULL | 1: set position counter to zero only once<br>0: always at an N channel event | 0/1 | RWE |
| 164 | Activate stop switch | Bit 0 — Left stop switch enable — When this bit is set the motor will be stopped if it is moving in negative direction and the left stop switch input becomes active<br>Bit 1 — Right stop switch enable — When this bit is set the motor will be stopped if it is moving in positive direction and the right stop switch input becomes active<br>Please see parameter 166 for selecting the stop switch input polarity. | 0… 3 | RWE |
| 165 | Actual encoder commutation offset | This value represents the internal commutation offset.<br>(0 … max. encoder steps per rotation) | 0… 65535 | RWE |
| 166 | Stop switch polarity | Bit 0 — Left stop switch polarity — Bit set: Left stop switch input is high active<br>Bit clear: Left stop switch input is low active<br>Bit 1 — Right stop switch polarity — Bit set: Right stop switch input is high active<br>Bit clear: Right stop switch input is low active | 0… 3 | RWE |
| 172 | P parameter for current PID | P parameter of current PID regulator. | 0… 65535 | RWE |
| 173 | I parameter for current PID | I parameter of current PID regulator. | 0… 65535 | RWE |
| 177 | Start current | Motor current for controlled commutation. This parameter is used in commutation mode. | 0… +20000 [mA] | RWE |
| 200 | Current PID error | Actual error of current PID regulator | -2147483648… +2147483647 | R |
| 201 | Current PID error sum | Sum of errors of current PID regulator | -2147483648… +2147483647 | R |
| 210 | Actual hall angle | Actual hall angle value | -32767… +32767 | R |
| 211 | Actual encoder angle | Actual encoder angle value | -32767… +32767 | R |
| 212 | Actual controlled angle | Actual controlled angle value | -32767… +32767 | R |
| 226 | Position PID error | Actual error of position PID regulator | -2147483648… +2147483647 | R |
| 228 | Velocity PID error | Actual error of velocity PID regulator | -2147483648… +2147483647 | R |
| 229 | Velocity PID error sum | Sum of errors of velocity PID regulator | -2147483648… +2147483647 | R |
| 230 | P parameter for position PID | P parameter of position PID regulator. | 0… 65535 | RWE |

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 234 | P parameter for velocity PID | P parameter of velocity PID regulator. | 0… 65535 | RWE |
| 235 | I parameter for velocity PID | I parameter of velocity PID regulator. | 0… 65535 | RWE |
| 241 | Sine initialization speed | Velocity during initialization in init sine mode 2. Refer to axis parameter 249, too. | -200000… +200000 [rpm] | RWE |
| 244 | Init sine delay | Duration for sine initialization sequence. This parameter should be set in a way, that the motor has stopped mechanical oscillations after the specified time. | 0… 10000 [ms] | RWE |
| 245 | Overvoltage protection | 1: Enable overvoltage protection. | 0/1 | RWE |
| 249 | Init sine mode | 0: Initialization in controlled sine commutation (determines the encoder offset)<br>1: Initialization in block commutation using hall sensors<br>2: Initialization in controlled sine commutation (use the previous set encoder offset) | 0, 1, 2 | RWE |
| 250 | Encoder steps | Encoder steps per rotation. | 0… +65535 | RWE |
| 251 | Encoder direction | Set the encoder direction in a way, that ROR increases position counter. | 0/1 | RWE |
| 253 | Number of motor poles | Number of motor poles. | +2… +254 | RWE |
| 254 | Hall sensor invert | 1: Hall sensor invert. Invert the hall scheme, e.g. used by some Maxon motors. | 0/1 | RWE |

# 5.1 Axis Parameter Sorted by Functionality

The following section describes all axis parameters that can be used with the SAP, GAP, STAP and RSAP commands.

**MEANING OF THE LETTERS IN COLUMN *ACCESS*:**

| Access type | Related command(s) | Description |
|---|---|---|
| R | GAP | Parameter readable |
| W | SAP, AAP | Parameter writable |
| E | STAP, RSAP | Parameter automatically restored from EEPROM after reset or power-on. These parameters can be stored permanently in EEPROM using STAP command and also explicitly restored (copied back from EEPROM into RAM) using RSAP. |

**MOTOR / MODULE SETTINGS**

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 253 | Number of motor poles | Number of motor poles. | +2... +254 | RWE |
| 25 | Thermal winding time constant | Thermal winding time constant for the used motor. Used for I²t monitoring. | 0... +4294967295 [ms] | RWE |
| 26 | I²t limit | An actual I²t sum that exceeds this limit leads to increasing the I²t exceed counter. | 0... +4294967295 | RWE |
| 27 | I²t sum | Actual sum of the I²t monitor. | 0... +4294967295 | R |
| 28 | I²t exceed counter | Counts how often an I²t sum was higher than the I²t limit. | 0... +4294967295 | RWE |
| 29 | Clear I²t exceeded flag | Clear the flag that indicates that the I²t sum has exceeded the I²t limit. | (ignored) | W |
| 30 | Minute counter | Counts the module operational time in minutes. | 0... +4294967295 [min] | RWE |
| 245 | Overvoltage protection | 1: Enable overvoltage protection. | 0/1 | RWE |

**ENCODER / INITIALIZATION SETTINGS**

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 31 | BLDC re-initialization | 1: restart the timer and initialize encoder. | (Ignored) | W |
| 159 | Commutation mode | 6: FOC based on hall sensor<br>7: FOC based on encoder<br>8: FOC controlled | 6, 7, 8 | RWE |
| 165 | Actual encoder commutation offset | This value represents the internal commutation offset.<br>(0 ... max. encoder steps per rotation) | 0... 65535 | RWE |
| 177 | Start current | Motor current for controlled commutation. This parameter is used in commutation mode. | 0... +20000 [mA] | RWE |
| 210 | Actual hall angle | Actual hall angle value | -32767... +32767 | R |
| 211 | Actual encoder angle | Actual encoder angle value | -32767... +32767 | R |
| 212 | Actual controlled angle | Actual controlled angle value | -32767... +32767 | R |
| 241 | Sine initialization speed | Velocity during initialization in init sine mode 2. Refer to axis parameter 249, too. | -200000... +200000 [rpm] | RWE |

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 244 | Init sine delay | Duration for sine initialization sequence. This parameter should be set in a way, that the motor has stopped mechanical oscillations after the specified time. | 0… 10000 [ms] | RWE |
| 249 | Init sine mode | 0: Initialization in controlled sine commutation (determines the encoder offset)<br>1: Initialization in block commutation using hall sensors<br>2: Initialization in controlled sine commutation (use the previous set encoder offset) | 0… 2 | RWE |
| 250 | Encoder steps | Encoder steps per rotation. | 0… +65535 | RWE |
| 251 | Encoder direction | Set the encoder direction in a way, that ROR increases position counter. | 0/1 | RWE |
| 254 | Hall sensor invert | 1: Hall sensor invert. Invert the hall scheme, e.g. used by some Maxon motors. | 0/1 | RWE |

**TORQUE REGULATION MODE**

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 6 | Max current | Set/get the max allowed motor current.<br>This value can be temporarily exceeded marginal due to the operation of the current regulator. | 0… +20000 [mA] | RWE |
| 150 | Actual motor current | Get actual motor current. | -2147483648… +2147483647 [mA] | R |
| 155 | Target current | Get desired target current or set target current to activate current regulation mode. (+= turn motor in right direction; -= turn motor in left direction) | -20000… +20000 [mA] | RW |
| 134 | Current regulation loop delay | Delay of the PID current regulator. | 0… +10 [50µs] | RWE |
| 172 | P parameter for current PID | P parameter of current PID regulator. | 0… 65535 | RWE |
| 173 | I parameter for current PID | I parameter of current PID regulator. | 0… 65535 | RWE |
| 200 | Current PID error | Actual error of current PID regulator | -2147483648… +2147483647 | R |
| 201 | Current PID error sum | Sum of errors of current PID regulator | -2147483648… +2147483647 | R |

**VELOCITY REGULATION MODE**

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 2 | Target speed | Set/get the desired target velocity. | -2147483648… +2147483647 [rpm] | RW |
| 3 | Actual speed | The actual velocity of the motor. | -2147483648… +2147483647 [rpm] | R |
| 9 | Motor halted velocity | If the actual speed is below this value the motor halted flag will be set. | 0 +200000 [rpm] | RWE |
| 133 | PID regulation loop delay | Delay of the position and velocity | 0… +10 [ms] | RWE |
| 234 | P parameter for velocity PID | P parameter of velocity PID regulator. | 0… +10 [50µs] | RWE |
| 228 | Velocity PID error | Actual error of PID velocity regulator | -2147483648… +2147483647 | R |
| 229 | Velocity PID error sum | Sum of errors of PID velocity regulator | -2147483648… +2147483647 | R |

### VELOCITY RAMP PARAMETER

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 4 | Max. absolute ramp velocity | The maximum velocity used for velocity ramp in velocity mode and positioning mode. Set this value to a realistic velocity which the motor can reach! | 0 +200000 [rpm] | RWE |
| 11 | Acceleration | Acceleration parameter for ROL, ROR, and the velocity ramp of MVP. | 0… +100000 [RPM/s] | RWE |
| 13 | Ramp generator speed | The actual speed of the velocity ramp used for positioning and velocity mode. | -2147483648… +2147483647 [rpm] | R |
| 146 | Activate ramp | 1: Activate velocity ramp generator for position PID control. (Allows usage of acceleration and positioning velocity for MVP command.) | 0/1 | RWE |

### POSITION REGULATION MODE

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 1 | Actual position | Set/get the position counter without moving the motor. | -2147483648… +2147483647 | RW |
| 0 | Target position | The target position of a currently executed ramp. | -2147483648… +2147483647 | RW |
| 7 | MVP Target reached velocity | Maximum velocity at which end position flag can be set. Prevents issuing of end position when the target is passed at high velocity. | 0 +200000 [rpm] | RWE |
| 10 | MVP target reached distance | Maximum distance at which the position end flag is set. | 0… +100000 | RWE |
| 161 | Encoder set NULL | 1: set position counter to zero at next N channel event. | 0/1 | RWE |
| 162 | Switch set NULL | 1: set position counter to zero at next switch event. | 0/1 | RWE |
| 163 | Encoder clear set NULL | 1: set position counter to zero only once<br>0: always at an N channel event | 0/1 | RWEP |
| 164 | Activate stop switch | Bit 0 — Left stop switch enable — When this bit is set the motor will be stopped if it is moving in negative direction and the left stop switch input becomes active<br>Bit 1 — Right stop switch enable — When this bit is set the motor will be stopped if it is moving in positive direction and the right stop switch input becomes active<br>Please see parameter 166 for selecting the stop switch input polarity. | 0… 3 | RWE |

| Number | Axis Parameter | Description | | | Range [Unit] | Access |
|---|---|---|---|---|---|---|
| 166 | Stop switch polarity | Bit 0 | Left stop switch polarity | Bit set: Left stop switch input is high active<br>Bit clear: Left stop switch input is low active | 0... 3 | RWE |
| | | Bit 1 | Right stop switch polarity | Bit set: Right stop switch input is high active<br>Bit clear: Right stop switch input is low active | | |
| 230 | P parameter for position PID | P parameter of position PID regulator. ( | | | 0... 65535 | RWE |
| 226 | Position PID error | Actual error of PID position regulator | | | -2147483648... +2147483647 | R |

**STATUS INFORMATION**

| Number | Axis Parameter | Description | Range [Unit] | Access |
|---|---|---|---|---|
| 151 | Actual voltage | Actual supply voltage. | 0... +4294967295 | R |
| 152 | Actual driver temperature | Actual temperature of the motor driver. | 0... +4294967295 | R |
| 156 | Error/Status flags | Bit 0: Overcurrent flag. This flag is set if the max. current limit is exceeded.<br>Bit 1: Undervoltage flag. This flag is set if supply voltage is too low for motor operation.<br>Bit 2: Overvoltage flag. This flag is set if the motor becomes switched off due to overvoltage.<br>Bit 3: Overtemperature flag. This flag is set if overtemperature limit is exceeded.<br>Bit 4: Motor halted flag. This flag is set if motor has been switched off.<br>Bit 5: Hall error flag. This flag is set upon a hall error.<br>Bit 6: TMC603 error flag<br>Bit 7: unused<br>Bit 8: unused<br>Bit 9: Velocity mode active flag<br>Bit 10: Position mode active flag.<br>Bit 11: Torque mode active flag.<br>Bit 12: unused<br>Bit 13: unused<br>Bit 14: Position end flag. This flag is set if the motor has been stopped at the target position.<br>Bit 15: unused<br>Bit 16: unused<br>Bit 17: $I^2t$ exceeded flag. This flag is set if the $I^2t$ sum exceeded the $I^2t$ limit of the motor. (reset by SAP 29 after the time specified by the $I^2t$ thermal winding time constant)<br><br>*Flag 0 to 15 are automatically reset. Only flag 17 must be cleared manually.* | 0...+4294967295 | R |

# 6 Global Parameter Overview (SGP, GGP, STGP, RSGP)

The following section describes all global parameters that can be used with the SGP, GGP, STGP and RSGP commands.

**TWO BANKS ARE USED FOR GLOBAL PARAMETERS:**

- Bank 0 (global configuration of the module)
- Bank 2 (user TMCL variables)

## 6.1 Bank 0

**PARAMETERS 64... 255**

Parameters below 63 configure stuff like the serial address of the module RS485 baud rate or the telegram pause time. Change these parameters to meet your needs. The best and easiest way to do this is to use the appropriate functions of the TMCL-IDE. The parameters between 64 and 85 are stored in EEPROM only. A SGP command on such a parameter will always store it permanently and no extra STGP command is needed.

*Take care when changing these parameters, and use the appropriate functions of the TMCL-IDE to do it in an interactive way.*

**MEANING OF THE LETTERS IN COLUMN *ACCESS*:**

| Access type | Related command(s) | Description |
|---|---|---|
| R | GGP | Parameter readable |
| W | SGP, AGP | Parameter writable |
| E | STGP, RSGP | Parameter automatically restored from EEPROM after reset or power-on. |

**GLOBAL PARAMETERS OF BANK 0**

| Number | Global parameter | Description | Range | Access |
|---|---|---|---|---|
| 64 | EEPROM magic | Setting this parameter to a different value as $E4 will cause re-initialization of the axis and global parameters (to factory defaults) after the next power up. This is useful in case of miss-configuration. | 0... 255 | RWE |
| 65 | RS485 baud rate | 0 9600 baud *Default*<br>1 14400 baud<br>2 19200 baud<br>3 28800 baud<br>4 38400 baud<br>5 57600 baud<br>6 76800 baud *Not supported by Windows!*<br>7 115200 baud | 0... 7 | RWE |
| 66 | Serial address | The module (target) address for RS485 and virtual COM port | 0... 255 | RWE |
| 73 | Configuration EEPROM lock flag | Write: 1234 to lock the EEPROM, 4321 to unlock it.<br>Read: 1=EEPROM locked, 0=EEPROM unlocked. | 0/1 | RWE |
| 75 | Telegram pause time | Pause time before the reply via RS485 is sent. | 0... 255 | RWE |
| 76 | Serial host address | Host address used in the reply telegrams sent back via RS485. | 0... 255 | RWE |
| 77 | Auto start mode | 0: Do not start TMCL application after power up (*default*).<br>1: Start TMCL application automatically after power up.<br>*Note: the current initialization has to be finished first.* | 0/1 | RWE |

| Number | Global parameter | Description | Range | Access |
|---|---|---|---|---|
| 81 | TMCL code protection | Protect a TMCL program against disassembling or overwriting.<br>0 – no protection<br>1 – protection against disassembling<br>2 – protection against overwriting<br>3 – protection against disassembling and overwriting<br>*If you switch off the protection against disassembling, the program will be erased first!*<br>*Changing this value from 1 or 3 to 0 or 2, the TMCL program will be wiped off.* | 0, 1, 2, 3 | RWE |
| 85 | Do not restore user variables | 0 – user variables are restored (*default*)<br>1 – user variables are not restored | 0/1 | RWE |
| 128 | TMCL application status | 0 –stop<br>1 – run<br>2 – step<br>3 – reset | 0… 3 | R |
| 129 | Download mode | 0 – normal mode<br>1 – download mode<br>*Attention:*<br>*Download mode can only be used if the motor has been stopped first. Otherwise the download mode setting will be disallowed.*<br>*During download mode the motor driver will be deactivated and the actuator will be turned off.* | 0/1 | R |
| 130 | TMCL program counter | The index of the currently executed TMCL instruction. | o… 2047 | R |
| 132 | Tick timer | A 32 bit counter that gets incremented by one every millisecond. It can also be reset to any start value. | 0… +4294967295 | RW |
| 255 | Suppress reply | 0 – reply (*default*)<br>1 – no reply | 0/1 | RW |

## 6.2 Bank 2

Bank 2 contains general purpose 32 bit variables for the use in TMCL applications. They are located in RAM and can be stored to EEPROM. After booting, their values are automatically restored to the RAM.

Up to 256 user variables are available.

**MEANING OF THE LETTERS IN COLUMN *ACCESS*:**

| Access type | Related command(s) | Description |
|---|---|---|
| R | GGP | Parameter readable |
| W | SGP, AGP | Parameter writable |
| E | STGP, RSGP | Parameter automatically restored from EEPROM after reset or power-on. |

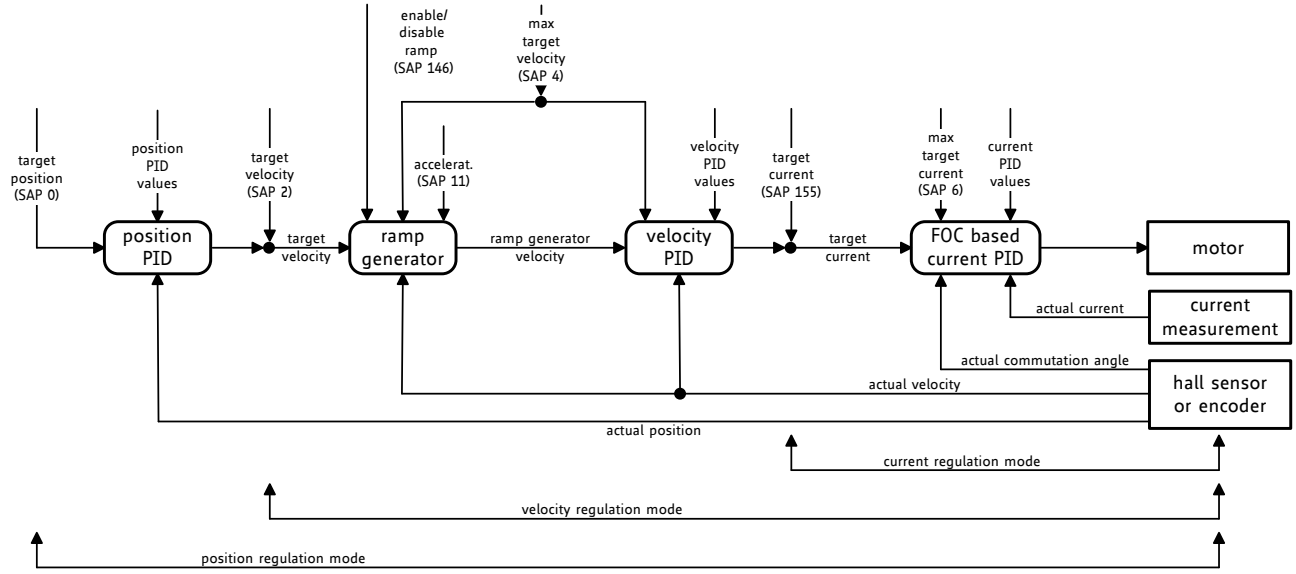
**GLOBAL PARAMETERS OF BANK 2**

| Number | Global parameter | Description | Range | Access |
|---|---|---|---|---|
| 0… 55 | General purpose variable #0… 55 | for use in TMCL applications | $-2^{31}$…$+2^{31}$ (int32) | RWE |
| 56… 255 | General purpose variables #56… #255 | for use in TMCL applications | $-2^{31}$…$+2^{31}$ (int32) | RW |

# 7 Motor Regulation

## 7.1 Structure of the Cascaded Motor Regulation Modes

The TMCM-1630 supports a current, velocity, and position PID regulation mode for motor control in different application areas. These regulation modes are cascaded as shown in figure 12.1. The individual modes are explained in the following sections.




**7.1 Cascaded regulation**

# 7.2 Current Regulation

The current regulation mode uses a PID regulator to adjust a desired motor current. This target current can be set by axis parameter 155. The maximal target current is limited by axis parameter 6.

The PID regulation uses three basic parameters: The *P* and *I* value as well as the *timing control value*.

### TIMING CONTROL VALUE

The timing control value (*current regulation loop multiplier*, axis parameter 134) determines how often the current regulation is invoked. It is given in multiple of 50µs:

$$t_{PIDDELAY} = x_{PIDRLD} \cdot 50\mu s$$

$t_{PIDDELAY}$ = resulting delay between two current regulation loops
$x_{PIDRLD}$ = *current regulation loop multiplier* parameter

For most applications it is recommended to leave this parameter unchanged at its default of 2*50µs. Higher values may be necessary for very slow and less dynamic drives.

### STRUCTURE OF THE CURRENT REGULATOR

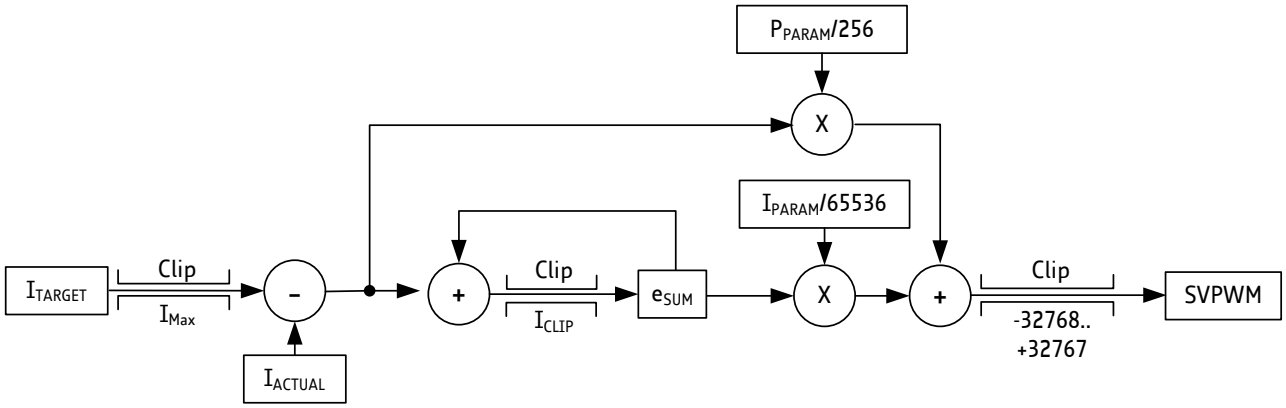



**Figure 7.2 Current regulation**

| Parameter | Description |
|---|---|
| $I_{ACTUAL}$ | Actual motor current (GAP 150) |
| $I_{TARGET}$ | Target motor current (SAP 155) |
| $I_{Max}$ | Max. motor current (SAP 6) |
| $e_{SUM}$ | Error sum for integral calculation (GAP 201) |
| $P_{PARAM}$ | Current P parameter (SAP 172) |
| $I_{PARAM}$ | Current I parameter (SAP 173) |

### PARAMETERIZING THE CURRENT REGULATOR SET

1. Set the *P* parameter and the *I* parameter to zero.
2. Start the motor by using a low target current (e.g. 1000 mA).
3. Modify the current *P* parameter. Start from a low value and go to a higher value, until the actual current nearly reaches 50% of the desired target current.
4. Do the same with the current *I* parameter.

For all tests set the motor current limitation to a realistic value, so that your power supply does not become overloaded during acceleration phases. If your power supply reaches current limitation, the unit may reset or undetermined regulation results may occur.

# 7.3 Velocity Regulation

Based on the current regulation the motor velocity can be controlled by the velocity PID regulator.

### TIMING CONTROL VALUE

Also, the velocity PID regulator uses a timing control value (*PID regulation loop delay*, axis parameter 133) which determines how often the PID regulator is invoked. It is given in multiple of 1ms:

$$t_{PIDDELAY} = x_{PIDRLD} \cdot 1\text{ms}$$

$t_{PIDDELAY}$ = resulting delay between two PID calculations
$x_{PIDRLD}$ = *PID regulation loop delay* parameter

*For most applications it is recommended to leave this parameter unchanged at its default value of 1ms. Higher values may be necessary for very slow and less dynamic drives.*

### STRUCTURE OF THE VELOCITY REGULATOR

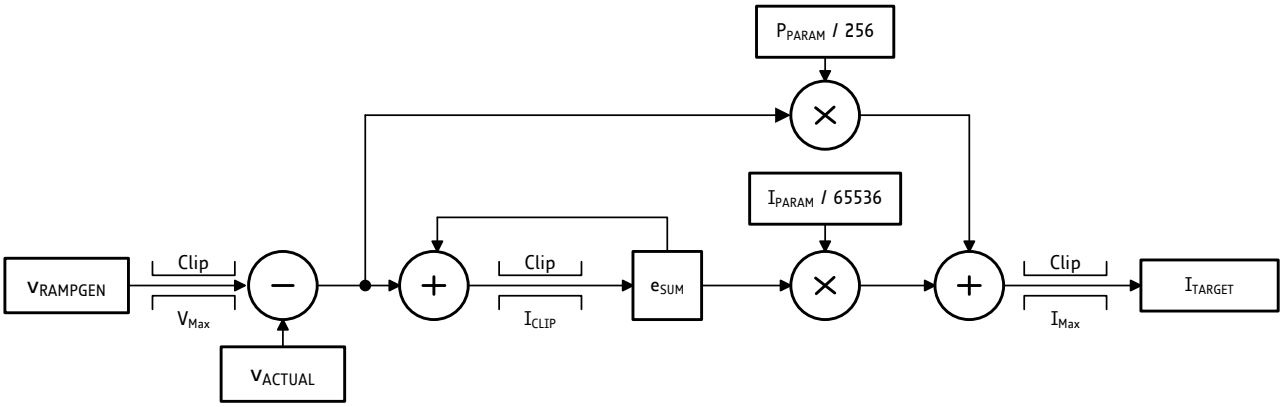



**Figure 7.3 Velocity regulation**

| Parameter | Description |
|---|---|
| $v_{ACTUAL}$ | Actual motor velocity (GAP 3) |
| $v_{RAMPGEN}$ | Target velocity of ramp generator (SAP 2, GAP 13) |
| $v_{Max}$ | Max. target velocity (SAP 4) |
| $e_{SUM}$ | Error sum for integral calculation (GAP 229) |
| $P_{PARAM}$ | Velocity P parameter (SAP 234) |
| $I_{PARAM}$ | Velocity I parameter (SAP 235) |
| $I_{Max}$ | Max. target current (SAP 6) |
| $I_{Target}$ | Target current for current PID regulator (GAP 155) |

### PARAMETERIZING THE VELOCITY REGULATOR SET

1. Set the *velocity I parameter* to zero.
2. Start the motor by using a medium target velocity (e.g. 2000 rpm).
3. Modify the *velocity P parameter*. Start from a low value and go to a higher value, until the actual motor speed reaches 80 or 90% of the target velocity.
4. The lasting 10 or 20% speed difference can be reduced by slowly increasing the *velocity I parameter*.

# 7.4 Velocity Ramp Generator

For a controlled start up of the motor's velocity a velocity ramp generator can be activated/deactivated by axis parameter 146. The ramp generator uses the maximal allowed motor velocity (axis parameter 4), the acceleration (axis parameter 11) und the desired target velocity (axis parameter 2) to calculate a ramp generator velocity for the following velocity PID regulator.

# 7.5 Position Regulation

Based on current and velocity regulators the TMCM-1630 supports a positioning mode based on encoder or hall sensor position. During positioning the velocity ramp generator can be activated to enable motor positioning with controlled acceleration or it can be disabled to support motor positioning with max allowed speed.

The PID regulation uses two basic parameters: the *P* regulation and a timing control value.

### TIMING CONTROL VALUE

The timing control value (*PID regulation loop parameter* - axis parameter 133) determines how often the PID regulator is invoked. It is given in multiple of 1ms:

$$t_{PIDDELAY} = x_{PIDRLD} \cdot 1\text{ms}$$

$t_{PIDDELAY}$ = the resulting delay between two position regulation loops

$x_{PIDRLD}$ = *PID regulation loop multiplier* parameter

*For most applications it is recommended to leave the timing control value unchanged at its default of 1ms. Higher values may be necessary for very slow and less dynamic drives.*

### STRUCTURE OF THE POSITION REGULATOR

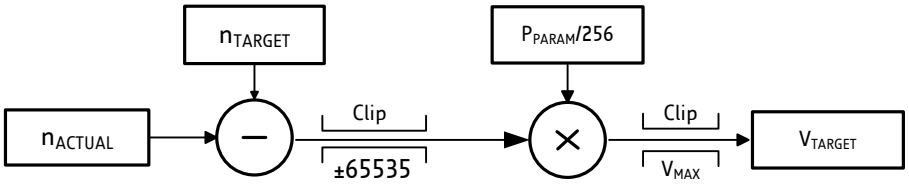



**Figure 7.4 Positioning regulation**

| Parameter | Description |
|---|---|
| $n_{ACTUAL}$ | Actual motor position (GAP 1) |
| $n_{TARGET}$ | Target motor position (SAP 0) |
| $P_{PARAM}$ | Position P parameter (SAP 130, SAP 230) |
| $V_{MAX}$ | Max. allowed velocity (SAP 4) |
| $V_{TARGET}$ | New target velocity for ramp generator (GAP 13) |

### PARAMETERIZING THE POSITION REGULATION

*Based on the velocity regulator only the position regulator P has to be parameterized.*

1. Disable the velocity ramp generator and set position *P* parameter to zero.
2. Choose a target position and increase the position *P* parameter until the motor reaches the target position approximately.
3. Switch on the *velocity ramp generator*. Based on the *max. positioning velocity* (axis parameter 4) and the *acceleration value* (axis parameter 11) the ramp generator automatically calculates the *slow down point*, i.e. the point at which the velocity has to be reduced in order to stop at the desired target position.
4. Reaching the target position is signaled by setting the *position end flag*.

**NOTE:**

- In order to minimize the time until this flag becomes set, the positioning tolerance *MVP target reached distance* can be chosen with axis parameter 10.
- Since the motor typically is assumed not to signal target reached when the target was just passed in a short moment at a high velocity, additionally the maximum target reached velocity (*MVP target reached velocity)* can be defined by axis parameter 7.
- A value of zero for axis parameter 7 is the most universal, since it implies that the motor stands still at the target. But when a fast rising of the *position end flag* is desired, a higher value for the *MVP target reached velocity* parameter will save a lot of time. The best value should be tried out in the actual application.

### CORRELATION OF AXIS PARAMETERS 10 AND 7, THE TARGET POSITION, AND THE POSITION END FLAG

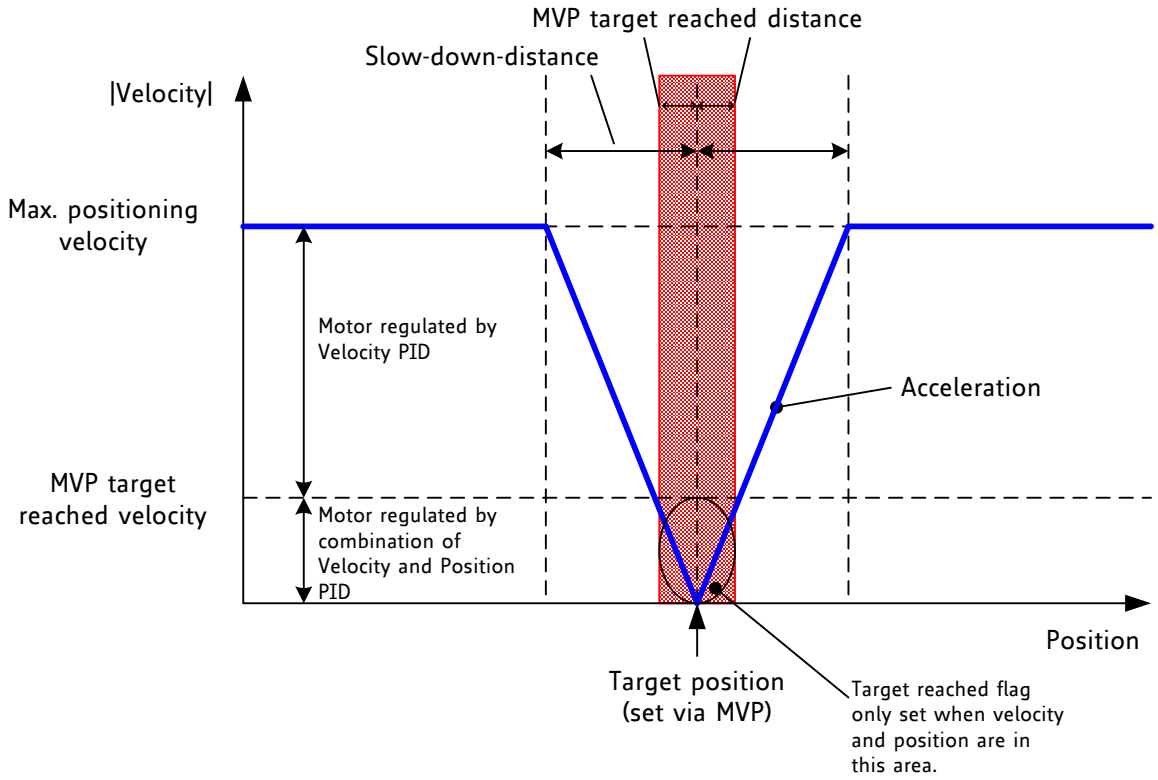

MVP target reached distance
Slow-down-distance
|Velocity|
Max. positioning velocity
Motor regulated by Velocity PID
Acceleration
MVP target reached velocity
Motor regulated by combination of Velocity and Position PID
Position
Target position (set via MVP)
Target reached flag only set when velocity and position are in this area.

**Figure 7.5 Positioning algorithm**

*Depending on motor and mechanics a low oscillation is normal. This can be reduced to at least +/-1 encoder steps. Without oscillation the regulation cannot keep the position!*

# 8 Temperature Calculation

Axis parameter 152 delivers the actual ADC value of the motor driver. This ADC value can be converted to a temperature in °C as follows:

$$\text{ADC} = actual\ value\ of\ GAP\ 152$$

$$\text{B} = 3434\ (material\ constant)$$

$$\text{R}_{\text{NTC}} = \frac{9011{,}2}{ADC} - 2.2$$

$$\text{T} = \frac{B * 298{,}16}{B + (\ln\left(\frac{R_{NTC}}{10}\right) * 298.16} - 273.16\ °C$$

Example 1:
ADC = 1000
$R_{NTC}$ ≈ 6.81
T ≈ 35°C

Example 2:
ADC = 1200
$R_{NTC}$ ≈ 5.31
T ≈ 42°C

# 9 I²t Monitoring

The I²t monitor determines the sum of the square of the motor current over a given time. The integrating time is motor specific. In the datasheet of the motor this time is described as *thermal winding time constant* and can be set for each module using axis parameter 25. The number of measurement values within this time depends on how often the current regulation and thus the I²t monitoring is invoked. The value of the actual I²t sum can be read by axis parameter 27. With axis parameter 26 the default value for the I²t limit can be changed (default: 211200). If the actual I²t sum exceeds the I²t limit of the motor, flag 17 (in axis parameter 156) is set and the motor pwm is set to zero as long as the I²t exceed flag is set. The actual regulation mode will not be changed. Furthermore, the I²t exceed counter is increased once every second as long as the actual I²t sum exceeds the I²t limit. The I²t exceed flag can be cleared manually using parameter 29 but only after the cool down time given by the *thermal winding time constant* has passed. The I²t exceed flag will not be reset automatically. The I²t limit can be determined as follows:

$$I^2t = \frac{I\ [mA]}{1000} * \frac{I\ [mA]}{1000} * t_{tw}\ [ms]$$

$I$ is the desired average current
$t_{tw}$ is the thermal winding time constant given by the motor datasheet

Example:

I²t limits for an average current of a) 1A, b) 2A, c) 3A and d) 4A over a thermal winding time of 13,2s.

a) $I^2t\ limit = \frac{1000\ [mA]}{1000} * \frac{1000\ [mA]}{1000} * 13200\ [ms] = 13200\ [mA^2 * ms]$

b) $I^2t\ limit = \frac{2000\ [mA]}{1000} * \frac{2000\ [mA]}{1000} * 13200\ [ms] = 52800\ [mA^2 * ms]$

c) $I^2t\ limit = \frac{3000\ [mA]}{1000} * \frac{3000\ [mA]}{1000} * 13200\ [ms] = 118800\ [mA^2 * ms]$

d) $I^2t\ limit = \frac{4000\ [mA]}{1000} * \frac{4000\ [mA]}{1000} * 13200\ [ms] = 211200\ [mA^2 * ms]$

# 10 Life Support Policy

TRINAMIC Motion Control GmbH & Co. KG does not authorize or warrant any of its products for use in life support systems, without the specific written consent of TRINAMIC Motion Control GmbH & Co. KG.

Life support systems are equipment intended to support or sustain life, and whose failure to perform, when properly used in accordance with instructions provided, can be reasonably expected to result in personal injury or death.

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Specifications are subject to change without notice.

# 11 Revision History

## 11.1 Firmware Revision

| Version | Date | Author | Description |
|---|---|---|---|
| 1.0 | 2011-MAY-16 | OK | First version |
| 1.46 | 2011-SEP-27 | ED | New version including hall*FX* parameters |
| 1.47 | 2012-JAN-26 | ED | hallFX parameters corrected |
| 1.48 | 2012-DEC-12 | ED | Axis parameter 178 added. |
| 2.05 | 2013-APR-14 | ED | New FOC version, several changes. |
| 2.07 | 2014-Jun-04 | ED | - Axis parameter 238 deleted (Mass inertia constant)<br>- Axis parameter 239 deleted (BEMF constant)<br>- Axis parameter 240 deleted (Motor coil resistance)<br>- Bug during Encoder-initialization (mode 2) with inverted encoder-signals fixed<br>- readability for encoder-, and hall-angle during controlled mode added |

## 11.2 Document Revision

| Version | Date | Author | Description |
|---|---|---|---|
| 2.00 | 2013-APR-02 | SD | Manual for new *Field Orientated Control* (FOC) firmware<br>- Commands SIO and GIO added.<br>- Axis parameters updated.<br>- Motor regulation updated.<br>- Axis parameter 209 deleted.<br>- Axis parameter 241 (sine initialization speed) added.<br>- Axis parameter 31 (BLDC re-initialization) added.<br>- Axis parameter 212 (actual controlled angle) new.<br>- Axis parameter 159 updated: new FOC controlled mode.<br>- Global parameter 77 (auto start mode) updated.<br>- Global parameter 129 (download mode) updated.<br>- Several axis parameter value ranges updated. |
| 2.01 | 2014-JUN-04 | ED | - Axis parameter 238 deleted (Mass inertia constant)<br>- Axis parameter 239 deleted (BEMF constant)<br>- Axis parameter 240 deleted (Motor coil resistance) |
| 2.02 | 2015-MAR-09 | JP | Removed more outputs option |

# 12 References

[TMCM-1630] TMCM-1630 Hardware Manual
[BB-1630] BB-1630 Hardware Manual
[TMCL-IDE] TMCL-IDE User Manual
[TMCL-BLDC] TMCL-BLDC User Manual
[TMC603] TMC603 Datasheet

Please refer to our homepage http://www.trinamic.com.